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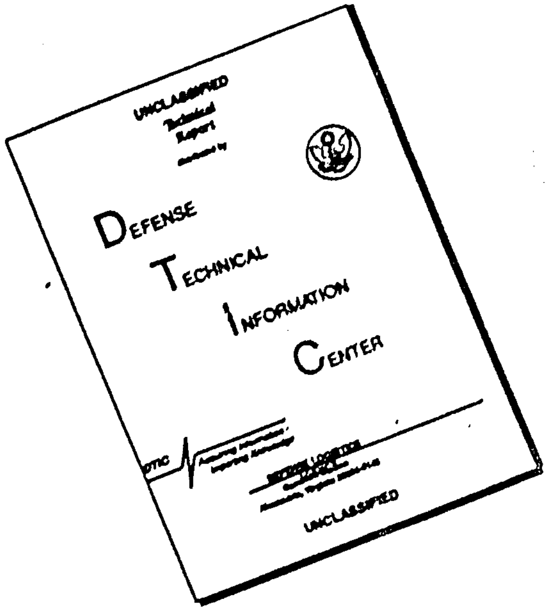

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Nap-of-Earth
Navigation Training

Research Memorandum 77-32

THE DEVELOPMENT OF A COMPOSITE SCORE FOR EVALUATING NAP-OF-THE-EARTH NAVIGATION

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THE DEVELOPMENT OF A COMPOSITE SCORE FOR EVALUATING NAP-OF-THE-EARTH NAVIGATION

Interviews with experienced nap-of-the-earth (NOE) instructor pilots (IPs) indicate there are two major observable factors to consider in measuring the skill of an NOE navigator: navigational accuracy and speed. The first is defined as the accuracy with which a navigator can locate the initial point of an NOE route, follow that route, identify checkpoints along the way and locate the landing zone or release point at the end of the route. This factor can easily be quantified by first determining the correct flying distance and then measuring each incremental distance resulting from inaccurate navigation. The IPs suggested all kinds of inaccuracies be judged as equally important, provided they are of the same magnitude. They suggested furthermore that the unit of measurement be the ratio incremental distance to the length of the route. Thus scores on longer routes would not be worse simply because of the increased opportunities to make errors.

The second major factor is the average speed the NOE navigator is able to maintain while flying along an NOE route. The poorer navigator will progress slowly, searching the visual world outside the helicopter, attempting to associate terrain features with features on the map. The helicopter may be required to hover frequently or to backtrack while the navigator becomes oriented or corrects errors. The better the navigator, the more rapidly he will progress. A superior NOE navigator, who is well oriented and skilled in terrain analysis, will have no need to search a wide area of terrain for recognizable features. He will concentrate on the terrain ahead and fly toward it directly.

It was deemed desirable, therefore, to combine accuracy and speed into a single composite score so that NOE navigators can be compared even when they navigate with different styles (slow and accurate versus fast with course errors) over routes of different lengths. The score thus obtained should be a quantifiable, objective measure of the navigation performance of an aviator navigating at terrain flight altitudes. This measure of terrain navigation is designated by the acronym, TENAV.

An earlier attempt by ARI (Farrell & Fineberg, 1976) to develop an objective measure accounted only for the accuracy factor, was insensitive to small errors (100m to 250m) and classed all errors between 250m to 1000m together. Instead, it is the judgment of NOE IPs and other terrain navigation experts that all errors of 100m or more should be registered on a continuous scale rather than merely being classified as 250 to 1000m or 1000m and greater. Furthermore, under the 1974 system a failure to locate an initial point is quantitatively as serious as any other course error. The outcome of such an error is the same in both cases; either the navigator becomes oriented and returns to course and continues the mission, or he fails to complete the mission.

Initially the IPs believed that Equation 1 would combine both the accuracy and the speed factors into a single score:

$$\text{TENAV Score} = \frac{E}{L \times S} . \tag{1}$$

E is each navigational error expressed in meters,
L the length of the NOE route in kilometers, and
S the average speed in kilometers per hour.

However, further exploration revealed that error magnitudes and speeds are not always linearly related. Specifically, a course deviation of, for example, 600m is more than twice as serious as a deviation of 300m. Similarly, a navigator who averages 60 km/hour on a particular NOE route is not considered twice as skilled as one averaging 30 km/hour. Subjection of various examples of errors and speeds to the IPs' informal judgment on how well they reflected navigational skill led to the conclusion that the TENAV score should be a power function of both errors and speeds. The following equation thus became the working hypothesis.

$$\text{TENAV Score} = \frac{\sum E^x}{L \times S^y} . \tag{2}$$

As demonstrated above, the exponent x would be larger than 1; whereas the exponent y would be less than 1. In order to determine the values of those exponents, the following magnitude estimation experiment was conducted.

METHOD

SUBJECTS

Twelve IPs, currently engaged in teaching NOE flight, navigation and tactics at the U.S. Army Aviation Center (USAAVNC), were subjects for this experiement.

TASKS AND PROCEDURE

There were two magnitude estimation tasks. One dealt with the seriousness of various magnitudes of navigational error and the other with the relative value of various speeds in NOE navigation.

Navigation Errors. This task required the subjects to estimate the seriousness of a given navigational error of one magnitude when compared with an error of a different magnitude. For example, "An error of 500m is _____ times as bad as a 200m error." After a brief introduction, the subjects were presented 22 such statements, one at a time, in random order. The standards ranged from 100m to 600m, the comparisons from 200m to 1200m. The subjects were required to fill in each blank comparing the two distances with quantitative measures of seriousness.

Speed. This task required the subjects to project the number of errors to be expected at one speed given a specified numbe. of errors at another. For example, "If you make 3 errors at 10 knots, you would make _____ errors at 30 knots." Twenty of these statements, with standards ranging from 10 to 60 knots and comparisons from 20 to 100 knots were presented in exactly the same manner as those described above.

DATA REDUCTION

The error magnitude data was converted to a common scale by assigning a value of 10 to a 100m error. Each subject's estimate, using 100m as the standard, then determined the value of a 200m error. Given these values, further estimates using 100m and 200m as standards determined the value of a 300m error. This process continued until values were assigned to all errors by each subject.

The speed value data were converted to a common scale by assigning a value of 1 to a speed of 10 knots. Each subject's estimates were handled as with errors above until all speeds were assigned estimated values.

The mean estimated values for each error magnitude and speed were calculated and plotted on log-log graph paper (Figure 1).

RESULTS

The plots of errors and speeds against their respective estimates of importance are linear on log-log paper (Figure 1). The slopes of these plots are the unknown exponents in Equation 2. The exponent for E, error magnitude, is 1.3. The exponent for S, speed, is 0.8. Thus, equation 2 becomes:

$$\text{TENAV Score} = \frac{\sum E^{1.3}}{L \times S^{8}}.$$

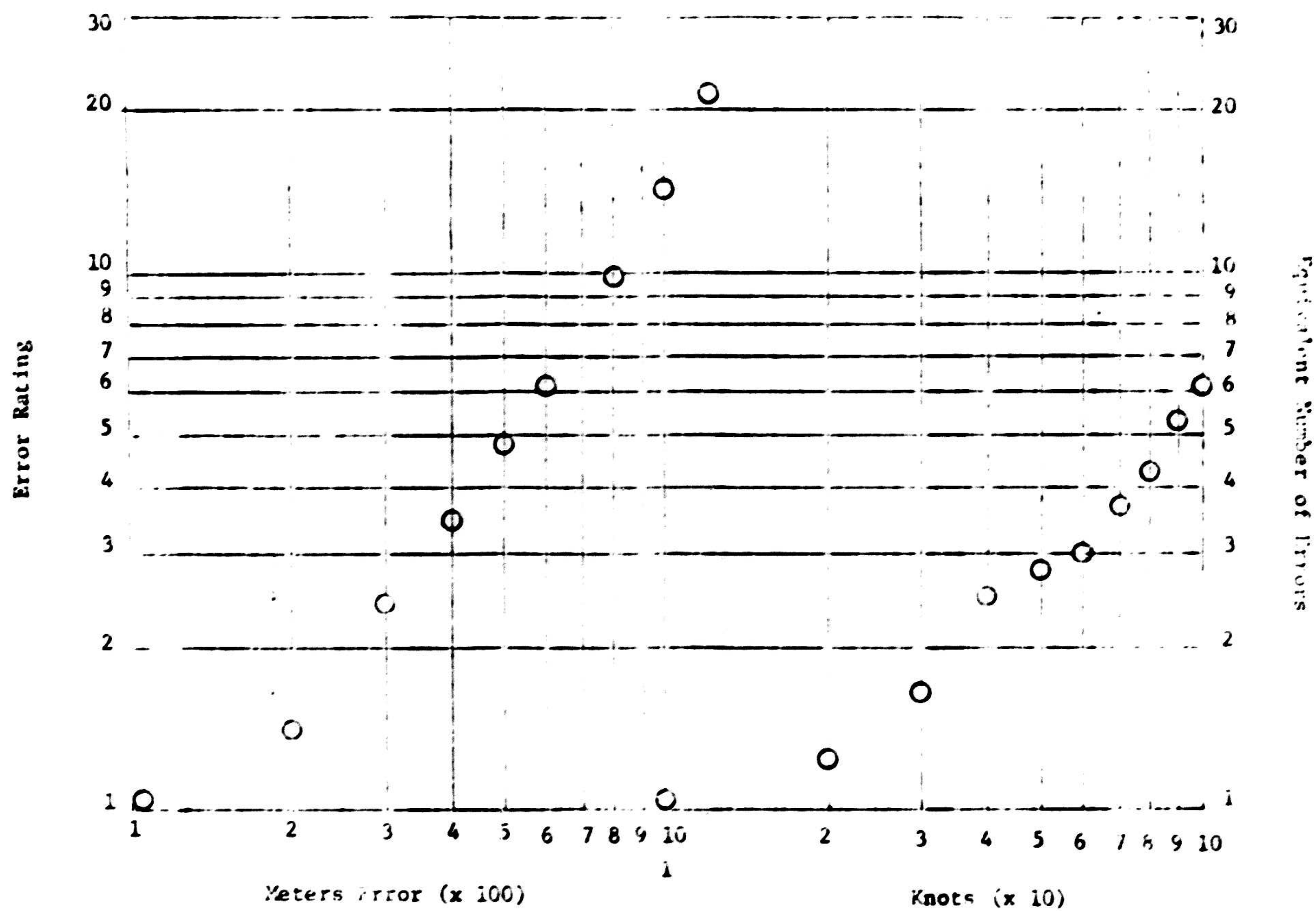

Figure 1. Navigation Error vs. Error Rating and Speed vs. Equivalent Number of Errors.

CONCLUSIONS

The linearity of the log-log plots in Figure 1 confirms the validity of the power functions in Equation 2. The values found for the exponents conform to the hypotheses derived from informal interviews. TENAV scores can be considered criterion measures of NOE navigation performance.

However, one further adjustment has been made. Because equation 2 was derived in a manner that did not reflect errors of less than 100m, many pilots, even students, were achieving perfect error magnitude scores of zero (see Holman, 1977). Obviously, equation 2 as written was incapable of reflecting the speed at which this perfect error score had been achieved. To correct this deficiency, equation 2 was amended to include an assumption that every pilot makes a nominal error of 100m. The result is equation 3:

$$\text{TENAV Score} = \frac{\sum E^{1.3} + 100^{1.3}}{L \times S^{.8}}. \qquad (3)$$

Using this equation, a superior navigation score is 1.0 or less. For example, a 15 km route navigated at 60 km/hour with no errors gets a score of 1.0. A 200m error added to this example results in a score of 3.5. Slowing the above speed to 40 km/hour further increases the score to 4.8. A poor performance such as 16 km route navigated at 30 km/hour with errors of 200m, 300m and 500m results in a score of 27.5.

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